SOILS

BY

HENRY W. NICHOLS

ASSOCIATE CURATOR OF GEOLOGY

GEOLOGY

LEAFLET 5

FIELD MUSEUM OF NATURAL HISTORY

CHICAGO

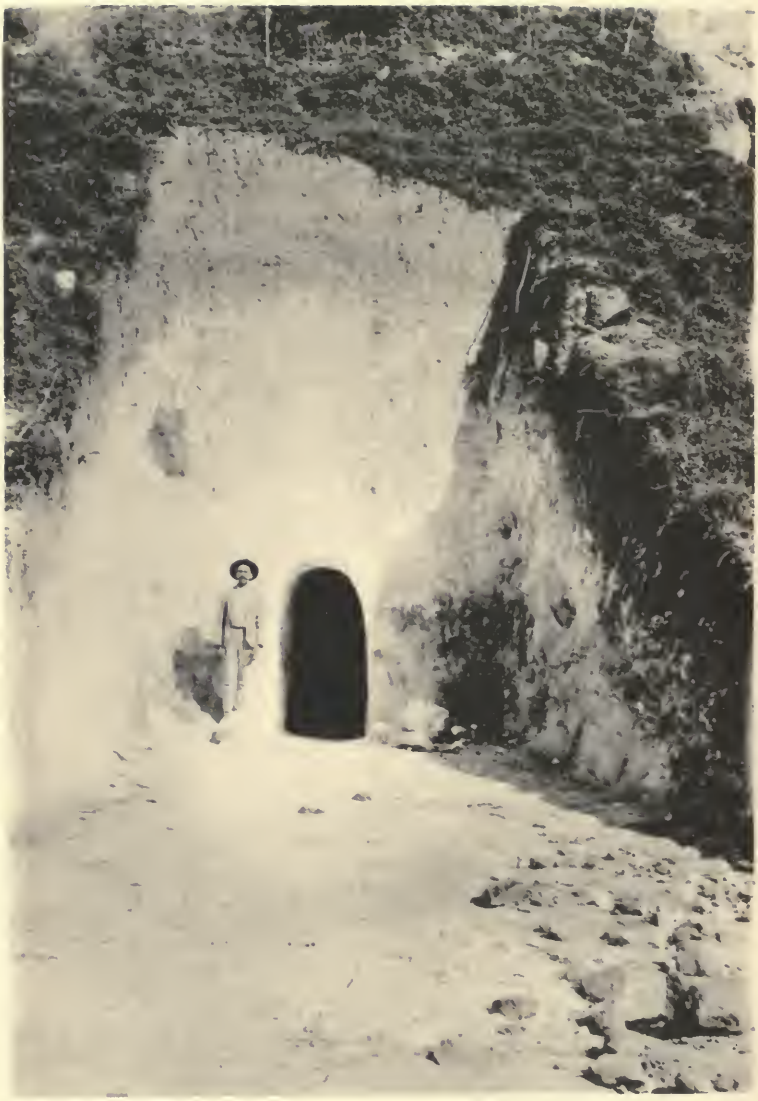
1925

LIST OF GEOLOGICAL LEAFLETS ISSUED TO DATE

No. 1.	Model of an Arizona Gold Mine	$ .10
No. 2.	Models of Blast Furnaces for Smelting Iron .	.10
No. 3.	Amber—Its Physical Properties and Geological Occurrence	.10
No. 4.	Meteorites	.10
No. 5.	Soils	.10

D. C. DAVIES, Director

FIELD MUSEUM OF NATURAL HISTORY
CHICAGO, U. S. A.



FRONTISPIECE. RESIDUAL SOIL.

In the tropics soil forms to great depths. The excavation and mine opening shown here are all in soil, formed by the disintegration of rock in place.

Brejauba, Brazil.

Capt. Marshall Field Geological Expedition to Brazil, 1922.

FIELD MUSEUM OF NATURAL HISTORY
DEPARTMENT OF GEOLOGY
CHICAGO, 1925

LEAFLET NUMBER 5

SOILS

It is a matter of ordinary observation that the hard rocks of the land surface of the earth are nearly everywhere concealed by a covering of loose materials of which the sands, gravels and clays are the most abundant and familiar. This covering is composed of fragments and other wastes from the disintegrating rock surfaces. It may be of any thickness from a fraction of an inch to hundreds of feet. It is upon the upper surface of this unconsolidated material that ordinary vegetation takes root and grows. In most places this surface has been so modified by exposure to air and weather and by the effects of growing and decaying vegetation, that it is much better able to support vegetation than is the unaltered material below. This modified surface is the soil. The unmodified material below is the subsoil. Soil is ordinarily shallow and varies in depth from a fraction of an inch to a few feet at most. In many arid regions and perhaps in some other places there is no perceptible difference between the surface which should be the soil and the subsoil below. In such cases the surface is spoken of as the soil and the distinction between soil and subsoil is not made. In regions, however, where the distinction between soil and subsoil is readily made, a surface from which the soil has been removed either by natural or artificial means is not ordinarily spoken of as the

soil merely because it happens to be at the surface. Such places in time develop a new soil to cover them.

FORMATION OF THE SOIL.

Soil is the product of the breaking down of solid rock. It contains fragments from the mechanical disintegration of rock and insoluble residues left from the chemical decomposition and solution of rock. With these are mingled smaller quantities of organic matter, detritus from the decay of vegetation. Rock is disintegrated by various mechanical agencies which produce fragments of all sizes from large boulders to dust particles of minutest size. The larger fragments, boulders, pebbles, gravels and sands are familiar to all. Besides the larger fragments quantities of rock powder and dust called rock flour are made. In many places, as around Chicago, this rock flour forms a not inconsiderable part of the soil. Those geological agencies which disintegrate are numerous and are continuously at work. Important among them is the action of frost. Water, filling crevices and pores in the rock, freezes and in freezing expands and wedges apart and breaks off fragments. Running water is another effective agent. Sand and gravel dragged over a rock bottom by the current of a stream grind away the rock at a fairly rapid rate. Boulders and pebbles grinding against each other as they are carried down stream by a rapid current are reduced to smaller size by abrasion. Wave action upon a pebble-covered beach has much the same effect. Where the rock surface is not covered by soil, expansion and contraction due to differences in temperature between day and night, cause the rock surface to disintegrate. There are many other sources of rock disintegration.

In glacial regions, among which northern Illinois is included, rock detritus from glaciation has a pro-

found effect upon the character of the soil, for in such regions the soil is largely composed of rock detritus of glacial origin. This material is the result of the grinding away of the surface rock by the scouring action of moving bodies of ice, which, filled with sand and gravel at their bases, acted much like gigantic pieces of sand paper.

ROCK DECOMPOSITION. Plate I. The durability of the stone fronts of our buildings would suggest that rock is weather proof and unalterable. Such is not the case. The impression of durability is due in part to the favorable position of stone in buildings and in part to the short lapse of time since even the first building was erected compared with the much longer periods during which the soil has been forming. The principal agent involved in the decomposition of rock is a very mild one, being merely rain and surface water. If this water were pure it would have little effect upon rock but its action is intensified by the effect of gases which it absorbs from the air and by other substances which it absorbs from the soil and acquires in other ways.

When rock decomposes a number of products are formed. Some of these dissolve in water and are washed away. Others are insoluble and remain. In spite of the varied composition of the different rocks, these insoluble residues are, when considered in a general way, surprisingly alike. Disregarding fragments of undissolved rock which are commonly present, the residues are sands and clays. The sands are particles varying in diameter from one twenty-fifth of an inch to sizes barely visible to the unaided eye. These are almost always fragments of the mineral quartz, one of the commonest rock minerals and one decidedly resistant to solution or alteration. Clay, the other important product of rock decomposition, is a very

finely divided material largely composed of compounds of silica and alumina combined with water, of which the mineral kaolin is typical. Most of the rock-forming minerals which are readily decomposed contain silica and alumina in quantity. From these substances combined with water, kaolin and a number of similar minerals which together form the basis of clay are formed. With these minerals there are usually present in clay a variety of others which assume clay-like properties because they are in the form of exceedingly minute particles.

ROCK SOLUTION. Some rocks, such as the limestones, are slowly soluble in water and under favorable conditions are completely removed in solution. Such rocks contain small quantities of insoluble materials as impurities. When the rock is dissolved these remain in the form of clay.

TRANSPORTATION. Rock detritus may remain in the place where it was formed. It is then called a residual soil. A residual soil from the solution of limestone is a clay which is usually very fertile. Residual soil from the decomposition of other rocks (Frontispiece) often attains great depths in the tropics. Often the change from soil at the surface through the subsoil to the solid rock is so gradual that there is no perceptible line of separation between subsoil and rock. In such soils the structure and general appearance of the parent rock are often preserved. More frequently soils have been transported and sorted by running waters, the ice of the glacial period or even by winds. By these means the sands, clays and gravels have been more or less assorted to mixtures which are quite different from those originally formed. Soils are sometimes classified according to the ways in which this transportation and redeposition has been accomplished. Thus we have besides numerous others, alluvial soils

PLATE I. FORMATION OF SOIL FROM IGNEOUS ROCK.

The series shows gradual rounding of angular blocks until the entire rock has disintegrated to soil.

Brighton, Mass.

deposited from water and glacial soils transported by the ice of the glacial period.

COMPOSITION OF SOIL.

Soils are essentially mixtures of some or all of the following: Gravel, sand, clay and organic matter in the form of humus. Carbonate of lime either as pulverized limestone, or in the form of shells or other organic residues is sometimes present in quantity. Upon the proportions and nature of these several components, the general character of the soil depends. While other substances present in small quantities have a profound effect upon soil fertility, circulation of air and water, ability to retain plant foods and such important matters are largely determined by the proportions of these major components present.

GRAVEL. Plate II. Gravel is composed of fragments of the rocks from which the soil has been derived. In the gravel is locked up much of the future fertility of the soil, to be given out by degrees as the pebbles decompose. Too large a quantity of gravel causes sterility by reducing the quantity of the more essential soil components. When the rock fragments of a gravel are less than about one twenty-fifth of an inch in diameter the material is called a sand.

SAND. Plate III. Rock fragments smaller than one twenty-fifth of an inch in diameter but large enough so that the individual grains may be readily distinguished by the naked eye, form sand. Sands found in soils are usually composed chiefly of the mineral quartz, so much so in fact, that sands are often spoken of as if they were wholly quartz. Yet practically all sands contain particles of other minerals than quartz and sometimes the other minerals form a large part of the substance of the sand. There are also sands from which quartz is nearly or quite absent. The specimen

shown in the soil collections, while predominantly of quartz, contains quantities of limestone, feldspar, mica, oxides of iron and other minerals. The sands about Chicago contain important quantities of limestone particles and generally grains of oxide of iron. The presence of sand in quantity causes a soil to be light, that is to work easily, be porous and consequently dry. As such a soil allows water to penetrate freely, soluble plant foods may be washed away, causing sterility. As air penetrates between the sand grains readily, a soil with much sand is seldom sour, as the organic acids formed by the decomposition of organic matter are rapidly oxidized and destroyed by the action of the air.

CLAY. Plate IV. This is a finely divided plastic mixture of minerals. Its most important constituents are hydrated silicates of alumina of which the mineral kaolin is the most typical and abundant. These silicates are derived from the decomposition of the feldspars and other aluminous minerals of the parent rock. As clay is tenacious and absorbs water readily, it makes a soil heavy, that is, resistant to implements of cultivation and to the passage of water. The absence of porosity makes circulation of air through clay difficult so that soils containing much clay readily become sour for the organic acids produced by the decomposition of organic matter are not rapidly destroyed by oxidation. Clay has the important property of retaining from waters passing through it, ammonia, phosphoric acid, potash and other valuable plant foods.

Soil in which the individual grains are nearly or quite imperceptible to the naked eye but are larger than the impalpably fine particles of a clay is called silt. Silt is intermediate in character between clay and sand, but as it is more or less clay-like in character according as its particles are finer or coarser it may be regarded for most purposes as an imperfect or impure form of clay.

PLATE II. GRAVEL.
Chicago Drainage Canal.
Photo by O. C. Farrington.

CARBONATE OF LIME. Carbonate of lime, which is present in small quantities in most soils and in large amounts in some, has a beneficial effect upon the fertility of the soil. Some authorities say that lime is the substance which holds commanding importance, aside from physical conditions, in controlling fertility. It is sometimes in the form of fragments and powder from broken-down limestone and sometimes in the form of shells or other organic remains. Its presence makes a soil more open and porous and it assists in holding plant foods. There is from one to three per cent of it in ordinary soils and some marls contain as much as ninety per cent.

HUMUS. Humus is the product of decaying organic matter. It comes from vegetation which has grown on the soil in which it is found. It gives soil a dark color and is a very important ingredient of fertile soils, as it provides the nitrogen necessary for vegetable growth and is also rich in the mineral plant foods. It is found in ordinary soils only in small quantities but forms half the bulk of some vegetable mold. Under certain conditions frequently encountered, some of the organic matter of humus assumes an acid character, making the soil sour. A sour soil is decidedly unfavorable to the growth of most crops. This sourness is counteracted by farmers in a number of ways —such as adding lime to neutralize the acid, exposure to strong sunlight, drainage and treatments increasing the circulation of air in the soil.

Many other substances are present in soils in small quantities and some of these have considerable effect in increasing or decreasing fertility.

PLANT FOODS.

While plants secure much of their food from the air, some mineral matter and some forms of organic

matter must be secured from the soil in which they grow. Many of these mineral plant foods, such as lime and oxide of iron, are practically always present in sufficient quantity. But certain others of the greatest importance are removed from the soil by cultivated crops faster than the decomposition of the soil particles can provide them. Hence their presence and quantity is a matter of vital importance to the farmer. These foods are listed below.

POTASH SALTS. These are derived from the decay of potash-bearing minerals, such as the feldspars of the rocks from which the soils were formed. The rock fragments composing the soil continue to decompose and gradually the potash-bearing minerals they hold give up potash in the form of soluble compounds. These may be (1) absorbed by vegetation, (2) stored in the soil, particularly if the soil is clayey, or (3) washed away and wasted.

PHOSPHATES. These plant foods also come from the parent rock of the soil. However, phosphate-bearing minerals are by no means as abundant in the rocks as are potash-bearing minerals, so that much of the phosphate used as plant food comes from the humus products of the decay of former vegetation. The same thing is true, probably in lesser degree, of potash compounds. This means the same phosphate and potash is used over and over again by succeeding generations of plants. As a consequence, when land which in its wild state was very fertile has been cultivated for some years, the fertility diminishes, for the potash salts and phosphate which were continually returned to the soil when the land was wild have been taken permanently from the soil as the crops were gathered. Fresh supplies of these foods from the decay of soil particles are not provided rapidly enough to compensate for the drain upon the supply. Therefore, if land is under

constant cultivation, it is necessary to replenish these plant foods from time to time by the application of fertilizers.

NITROGEN. Nitrogen is another element of plant life which must be provided from the soil. Most of it is in the form of humus from previous vegetation. Important quantities are also provided by certain bacteria which abstract and fix nitrogen from the air. Also some ammonia and acid compounds of nitrogen are formed from the nitrogen of the air during thunder storms and are washed into the soil by rain water. Like the potash and phosphates, the nitrogen of a soil is depleted by the removal of crops and must be replaced by the application of manures and fertilizers or by the growing of crops which promote the growth of the nitrogen-fixing bacteria.

OTHER PLANT FOODS. There are a number of other mineral plant foods which, as already stated, are practically always present in sufficient quantity for plant growth. These include lime, iron, silica and others which are either needed only in small quantity or are always present in abundance. The application of lime to a soil is seldom necessary because of an insufficient supply for plant food, but rather to modify the physical condition of the soil or to render other plant foods more readily available.

SOIL POISONS.

Substances are sometimes present in soils which greatly diminish their fertility or even induce complete sterility. On the beaches and marshes of the seashore, ordinary vegetation cannot grow owing to the presence of salt. A special vegetation that has developed toleration for salt to so high a degree that it cannot exist without it takes the place, therefore, of ordinary upland vegetation. Soluble alkali salts which

are often present in the soils of arid and semi-arid regions have the same effect on plant growth as the salt of the sea-shore. Another kind of soil poison which has been recognized in recent years is that believed to be produced by poisonous secretions from growing crops which interfere with the subsequent growth of the same crops on the same land.

CLASSIFICATION OF SOILS.

A number of soil classifications are in use and are adapted to different methods of soil study. For ordinary use, where exhaustive study of the subject is not contemplated, a classification which has arisen through centuries of agricultural observation is universally employed in farming regions. This separates soils into groups which are determined principally by the sizes of the soil particles. This classification recognizes four fundamental classes, gravels, sands, loams and clays, to which are added two other groups, marls and vegetable molds on account of the great influence on the fertility of soils which lime and organic matter exercise.

GRAVEL when pure consists of rock fragments over one twenty-fifth of an inch in size. As gravels are absolutely sterile, they are not, strictly speaking, soils at all.

SANDY SOILS consist essentially of sand with which may be mixed small quantities of vegetable mold and clay. The pure sands, as those of many beaches and dunes, are practically sterile, so that they may be considered as soils only when some humus or clay is present. The humus of such sandy soils provides and the clay retains plant foods so that such soils may be fairly fertile. However, as the open texture of the sands is such that water circulates readily, plant foods are quickly leached out and therefore such soils tend

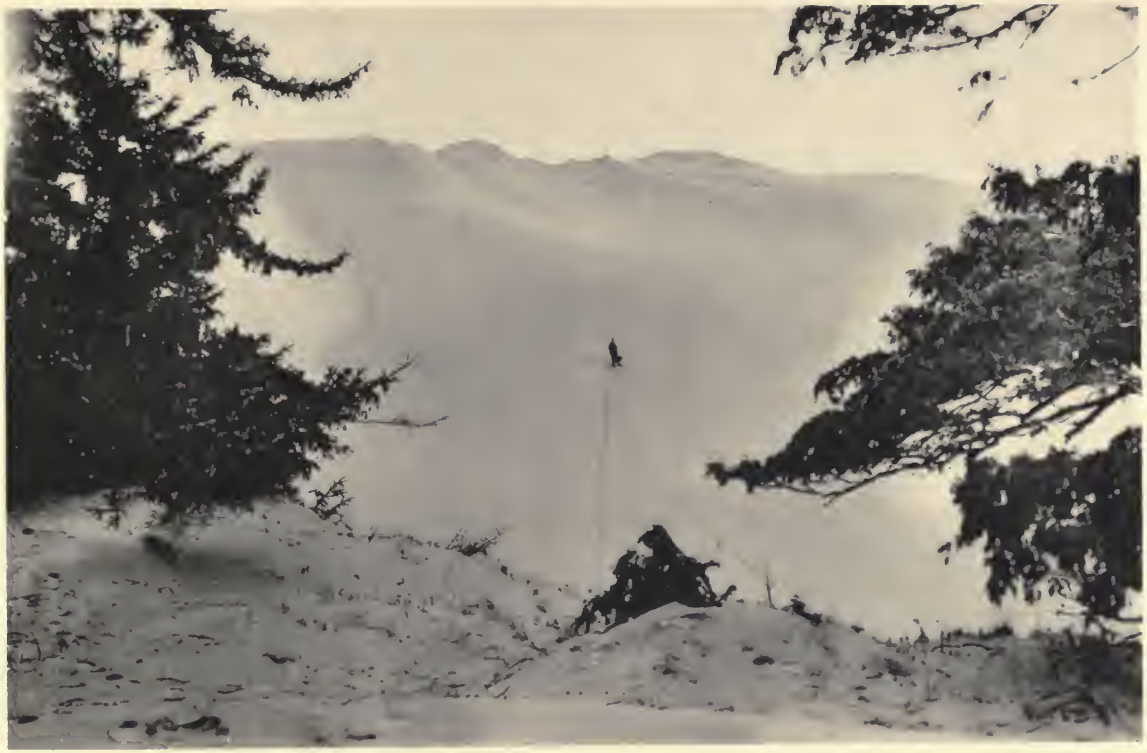


PLATE III. SAND.

Sand Dunes, Coos Bay, Oregon.

Photo by Huron H. Smith.

to be sterile. As such soils allow water to drain away readily they do not retain moisture and this in most climates is unfavorable for fertility. The porosity of sandy soils promotes the rapid circulation of air which oxidizes any organic acid present in the humus so that such soils are seldom sour. As there is no cohesion between the sand grains, sandy soils yield readily to agricultural tools and are easily worked. They are often called light soils, not because they weigh little, but because they are easily worked. When a soil contains less than twenty per cent of sand, the properties of clay begin to be noticeable and the soil becomes a loam.

LOAM. When a soil composed largely of sand yet contains sufficient clay so that the properties of clay become apparent, the soil is a loam. A loam therefore presents some of the qualities of both sandy and clayey soils. It has in lesser degree the porosity of sandy soils and yet shows a little of the tenacity and plasticity of clay soils. The loams are our most valuable soils. They have porosity so that they are usually kept sweet by circulating air and yet the pores are sufficiently stopped by clay so that water does not drain off readily and therefore they are not rapidly impoverished by leaching of the plant foods nor do they dry out as rapidly as the sands in times of drought. Loam particles possess some cohesion from the clay present but this cohesion is not sufficient to make the soil heavy to work. Loam soils may be divided into the two groups of sandy loams and clay loams.

No exact percentage of sand and clay can be stated which separates a loam from a sand or clay soil, for the distinction is based upon a combination of the effects of sand and clay upon the properties of the soil. As sands are coarser or finer they are able to impress

their character upon the soil more or less strongly. Clays also vary in physical character so that the same amount of different clays will affect a soil differently.

CLAY OR HEAVY SOILS. These soils are called heavy because they offer much resistance to the tools used in cultivation. They are composed of clay with some sand and humus. These soils in their natural state tend to be wet and sour and hence, sterile. The tenacity of the clay makes tillage difficult. Properly cultivated they are often very fertile. They are less easily exhausted by cultivation than most soils.

MARLS. Plate V. Soils containing much lime are distinguished from other soils by the name marl. This distinction is made because of the noticeable effect, usually beneficial, of carbonate of lime on soil. So great is the modification of soil by lime that marls high in lime are applied to other soils as fertilizers. A shell marl is a marl in which the carbonate of lime is present in the form of shells. Marls are light, porous soils which do not become sour and retain plant foods well. They frequently contain some of the plant foods in unusual quantity.

HUMUS SOILS. Soils colored by more than five per cent of humus form a very fertile group of soils. They include vegetable mold and muck.

Vegetable mold is a thin, black soil formed in forests and elsewhere by the decay of vegetation.

Muck is a soil formed in wet places by the arrested decay of vegetation in the presence of water. In their natural state mucks are wet and sour but when properly prepared for cultivation they are of unusual fertility.

The simple soil classification above given has been elaborated by the United States Department of Agriculture into a complex system suited for use in the

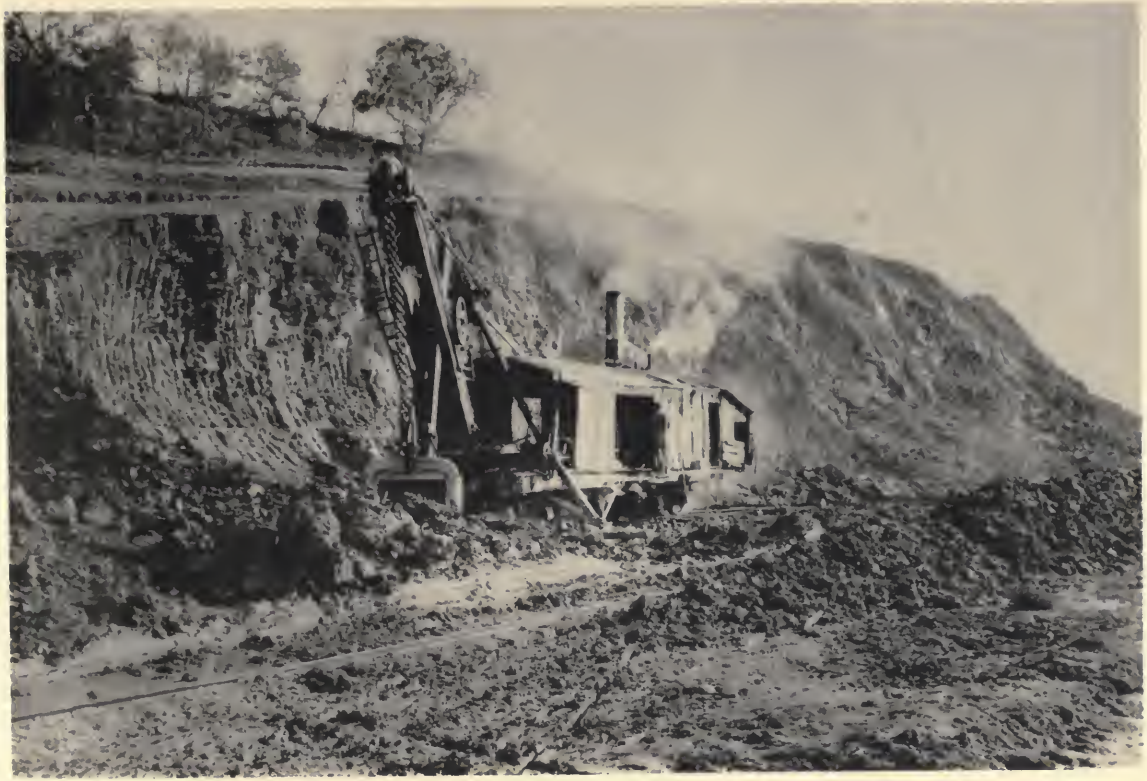


PLATE IV. CLAY.
Ada, Oklahoma.
Photo by G. S. Eaton.

intensive study of soils by precision methods. A collection of soils arranged according to this more elaborate system is shown in the Museum in a separate case.

NOTE.

The soil is absolutely essential for human life and progress. Consequently it has been much studied and much is known about it. The more essential parts of this knowledge are of such a nature that they can be illustrated by specimens and the Museum has prepared collections to illustrate these. They show the origin, nature, composition and kinds of soil and some other features such as plant food in soil. Other often important facts concerning soils are of such a nature that they can not be well illustrated by specimens. This leaflet treats of only such aspects of the soil as the collections illustrate. The Museum soil collection is exhibited in the southwest quarter of Hall 36 on the second floor of the building.

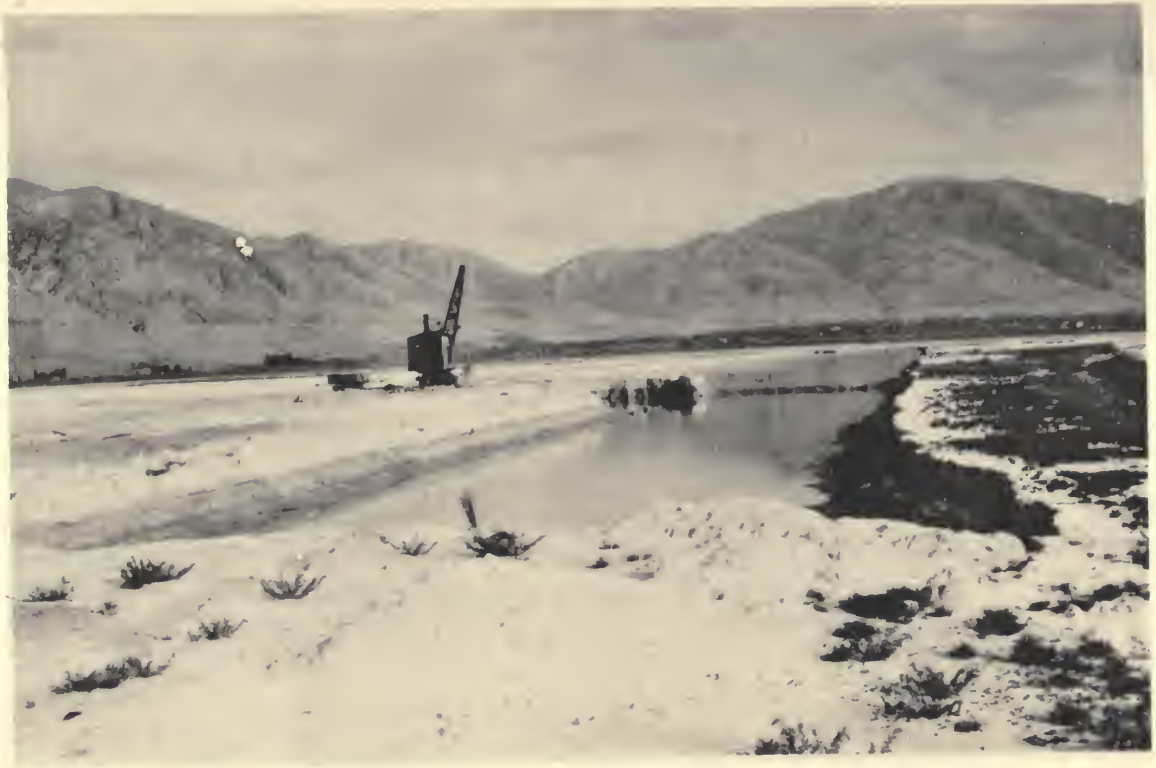


PLATE V. MARL.
Near Brigham City, Utah.
Photo by G. S. Eaton.

PRINTED BY FIELD MUSEUM PRESS